Major carbon cycles and the control of atmospheric CO_2

I. Look at different time scales of the carbon cycle
   A. break the overall cycle in to cycles of different scales
   B. begin to see how man is affecting the processes

II. Short-term biological cycles (years to decades)
   A. Does not include calcite ppt/dissln. – also does not include anthropogenic effects
   B. photosynthesis/respiration
      1. $CO_2 + H_2O = CH_2O + O_2$
   C. these two cycles are almost nearly balanced
      1. both in oceans and on land
      2. little net loss **show my box model with number**
   D. some transport of OC from land to oceans
      1. several options
         a. net terr. primary prod. that escapes resp. on land and is transported to oceans via rivers
         b. uplifted kerogen that escapes weathering on continents
      2. regardless of source most of terr OC appears to be oxidized in oceans
   E. in oceans a small amount of marine-derived OM is also buried in seds
      1. enters the long-term carbon cycle
      2. leaves behind some O_2 in the atmos.
   F. these short-term cycles process a lot of CO_2
      1. ~30-50% of the atmospheric CO_2 is consumed and returned per year
      2. leads to the short (~3 yr) residence time of atmospheric CO_2

III. Long term organic carbon cycle (several million years)
   A. involves OM in sediments, fossil fuels and atmos. O_2 and CO_2 **Fig. 6-5**
   B. start with burial of OM in sediments from short-term cycle
      1. subjected to burial (incr. P and T)
         a. most ends up as kerogen
         b. dispersed organic matter in shales
      2. some undergoes high P and T alteration to form oil, natural gas
         a. generally found in shales but some OM can also migrate and form segregated deposits
      3. coal
         a. forms from the alteration of terr. OM
      4. think of coal, oil and gas an non-renewable energy source because these processes take millions of years to transform OM into oil/coal
      5. OM in shales represents the largest reservoir of OM on the Earth's sfc
         a. consistent with its geol cycle it has a long residence time (~200 my)
   C. this removal is balanced by kerogen oxidation
      1. uplift of this material completes this portion of the carbon cycle
      2. most weathering/oxidation of kerogen occurs on land
   D. this cycle also effects atmos. O_2 **show equations**
      1. $CO_2 + H_2O = CH_2O + O_2$
      2. net burial of OM leaves O_2 in the atmosphere
      3. pyrite burial/oxidation also plays a role here

a. this process also requires OM as an intermediate (to catalyze sulfate reduction at earth sfc. conditions)

4. oxygen in atmos controlled by a balance between pyrite and OM burial in sediments and their later oxidation on land
   a. if this balance didn't occur atmos O_2 would increase to ~150% of present levels in several million years
   b. would also lead to complete depletion of atmos. CO_2 in <10,000 yrs
   c. see text for further discussion on the controls of atmos O_2

IV. Long term inorganic carbon (geological) cycle (100's of million years)

A. balance between weathering rxns and plate tectonics **show Fig. 8.17**
   1. weathering on silicate rocks on land
   2. removes CO_2 from atmos., transfers it to the ocean as bicarbonate
      a. diss. silica transported as well
   3. removal of bicarbonate as calcite & burial in marine sediments
      a. similar biol. processes remove diss. SiO_2
   4. subduction of sediments and tectonic activity
      a. release this CO_2 back to atmos.
   5. similar types of rxn. affect other cations as well (Mg, Na)

B. processes began early in the earth's history
   1. leads to long-term changes of CO_2 **Fig. 12-3**
      a. drop in CO_2 associated with incr in solar luminosity
   2. Berner calcs are consistent with these trends over shorter time scales **Fig. 6.4**

C. this cycle is a balance between back to **Fig. 8-17**
   1. weathering (takes up CO_2)
   2. calcite ppt. in oceans and tectonics/metamorphism (releases CO_2)

D. high CO_2 back to Fig. **6.4**
      a. rapid plate tectonics and metamorp. release CO_2
      b. Cret. (K) and mid-Paleozoic (Camb. -> Devonian; -C- to D)
      c. warm periods in the Earth's climate
   2. low CO_2
      a. less vigorous plate tectonics, more weathering and calcite burial
      b. Carbon. -> Triassic, most of the Cenozoic (Tert.)
      c. cooler temps and ice ages

E. carbonate-silicate cycle related to climate **Fig. 8-18**
   1. vulcanism/tectonic activity likely not strongly affected by atmos. CO_2 or global climate
      a. e.g. – an increase in CO_2 could occur if there were an increase in tectonic activity
      b. acts a s a forcing function on atmos CO_2
   2. these processes then affect CO_2
   3. this cycle has a negative feedback loop associated with it that stabilizes climate from these or other perturbations
      a. incr sfc temp due to increasing solar luminosity
      b. lead to a drop in CO_2 by increased weathering
      c. may also induce ppt. of carbonate minerals

F. a geological cycle BUT organisms clearly play a role
   1. calcite and silica ppt. are biol. processes

2. rates of weathering affected by plants
3. Gaian control or modulation ?

V. Effect of man on the carbon cycl **Fig. 10-16**

A. pre-industrial
1. steady state on decadal to century time scales
2. prior to extensive land use changes (deforestation) and fossil fuel burning
3. ocean a net source of CO_2 **show my version**
   a. neutralization of river bicarbonate (C_{ing})
      (i) by-product of weathering
   b. oxidation of riverine C_{org} derived from terr. PP
      (i) carbon cycling in the long term cycles plus terr OC
4. burial of C_{org} can be either
   a. riverine C_{org} that escapes oxidation in the oceans (burial of terr. C_{org})
   b. burial of "newly" fixed marine Corg
      (i) carbon produced in the short term C cycle
   c. data suggests that burial of marine OC predominates
   d. most terr. OM transported to oceans appears to be oxidized in the oceans

B. human impacts **fig. 10.16b**
1. the oceans are now a sink for CO_2
   a. uptake of fossil fuel CO_2
2. increased susp. sediment load and nutrient transport and deposition
3. much more pronounced in the coastal zone
   a. leads to coastal eutrophication
   b. low oxygen conditions in these environments
   c. recent studies also suggest that much of the excess N may be denitrified
   d. doesn't necessarily escape the coastal zone

VI. fossil fuel burning **C cycle figure**

A. transferring a rel. large amount of CO_2 into the atmos. with no equivalent rapid uptake mechanisms
1. ocean uptake limited by circulation and biol. pump (nutrients)
2. uptake by terr. systems does not appear to be rapid enough
3. accumulates in the atmosphere

B. how will this increase affect climate
1. depends on the time scales of the increase in atmospheric conc. vs. time scales of the resulting changes in earth's climate/heat balance/ocean or atmos. circulation
2. also whether or not these changes result in positive or negative feedback responses in the Earth's climate system

C. more later